7. The results obtained in the Belfast Hospital for Sick Children compare very favourably with those published from other centres.

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Radiological Diagnosis of Brain Tumours (including Ventriculography)*

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RADIOLOGY plays a comparatively small though important part in the diagnosis of brain tumours. It is essentially a question of team-work divided between the neurological surgeon, the neurologist, the occulist, and radiologist. The neurological surgeon is the captain of the team, and it is he who collects together and correlates the evidence deduced from the various methods of examination, finally putting them together as one assembles a jigsaw puzzle, until the picture is complete and the diagnosis is established. In some cases the interpretation of the radiographs is easy, but in many cases it is extremely difficult, and calls for considerable experience and an accurate knowledge of the anatomy of the brain, the pathology of brain tumours, and every detail of the procedure of the examination which has been carried out. For this reason team-work is essential, for in many cases the radiologist does not possess the information upon the clinical side of the case to enable him to make a diagnosis from the X-ray appearances alone. In some instances the X-ray diganosis can be made without any reference to the clinical history or neurological findings, but in many others localization of a tumour is extremely difficult, even while utilizing every method of examination at our disposal.

I should like, first, to refer very briefly to the routine examination of the skull, for such an investigation always precedes ventriculography and may give valuable

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information as to the existence of a brain tumour, its site, and, in some instances, even its nature. This examination may be quite a simple one: a plain lateral view, an antero-posterior, or an occipital view will suffice in most cases.

Now, what to look for in such an examination is best answered by referring you to a table compiled by Karl Kornblum of Philadelphia, showing the incidence of various röntgen manifestations of intracranial tumour occurring in a series of 446 verified cases.

1. Deformation of the sella turcica - - -	64.6 per cent.
2. Convolutional atrophy - - - -	8.8 per cent.
3. Calcification of the tumour - - -	6.5 per cent.
4. Widening of the sutures - - - -	4.6 per cent.
5. Local bone erosion - - - -	2.9 per cent.
6. Local hyperostosis - - - -	1.8 per cent.
7. Lateral shift of the pineal body - - -	1.8 per cent.
8. Widened diploic channels - - -	0.2 per cent.

1. *Deformation of the Sella Turcica.*—One must be careful in diagnosing abnormalities in the sella turcica, for the size varies greatly within the normal. Decalcification and erosion of the clinoid processes and floor of the sella is a much more reliable guide of disease than size. Only when greatly enlarged or altered in shape should one diagnose pathological change. While deformation of the sella is an extremely important indication of the presence of an intracranial tumour, it cannot be taken as infallible evidence of an intrasellar lesion, or even as an indication of a tumour in close proximity to the pituitary fossa. Increased intracranial tension from a tumour in the posterior cranial fossa may produce destructive bone changes in the sella turcica and anterior cranial fossa. (Plate 1.)

2. *Convolutional Atrophy.*—This sign is of very limited value, in my opinion, for one has no standard of normality from which to draw deductions. The appearance is produced by pressure of the convolutions of the brain against the inner table of the skull, and is present in some degree in most children and young adults. With abnormal intracranial pressure these so-called digital markings become more pronounced, but the difficulty lies in distinguishing between what is physiological and what is pathological.

The appearance of convolutional atrophy gains in significance with the age of the patient.

Convolutional atrophy requires several months for its production, so must not be looked for as a result of sudden increase in pressure following head injuries or fracture of the skull.

3. *Gaping Sutures.*—Of much more value as a sign of increased intracranial pressure is widening or gaping of the sutures. For anyone who is experienced in the examination of skull-films, the detection of such a change is easy, and is positive evidence of abnormal tension.

4. *Calcification.*—One of the most reliable X-ray signs of an intracranial tumour is calcification of the growth. It is not of common occurrence, as shown by Kornblum's table, i.e., 6.5 per cent. of the series of cases analyzed.

Such changes take place most frequently in gliomas, and may be found anywhere within the cranium, though not often below the tentorium. Calcification above the pituitary fossa is usually associated with a hypophyseal duct-tumour or Rathke pouch. The pineal body is calcified in a large percentage of normal people, and must not be mistaken for tumour. Displacement of the pineal in a lateral direction should be looked for; but in connection with this one must sound a word of warning. A unilateral calcification of a choroid plexus should not be mistaken for a displaced pineal body. Calcification of the choroid is usually larger than a pineal body, and is generally bilateral. Ossified plaques in the falx cerebi are recognized by their central position and linear contour, as seen in the antero-posterior view.

Calcified Pachionian bodies lie on either side of the sagittal suture in the parietal region. Calcification may occur in the meninges following trauma.

5. *Localized Bone Erosion.*—I have already referred to erosion in the region of the sella turcica, but destructive changes may also be associated with acoustic tumours of the petrous bone and with meningeoma. In the case of the latter it is not uncommon to find also widening of the diploic channels.

6. *Localized Hyperostosis.* — Frequently found in association with an underlying meningeoma, and usually found in the anterior part of the cranium. The whole thickness of the skull is involved in these cases, and the condition should be distinguished from benign hyperostosis, which involves only the inner table of the skull and is of little significance.

Pineal displacement and widening of the vascular channels in the bones I have already referred to, and do not wish to add to what I have said. Changes in the optic foramina also deserve mention, but it would take too much time to elaborate upon this subject.

VENTRICULOGRAPHY.

To Walter Dandy of Baltimore belongs the credit for discovering a method of localizing brain tumours by air injection of the ventricles. His first published report of this new procedure was in the "Annals of Surgery" for July, 1918. While it would be interesting to describe at some length Dandy's early investigations in this connection, and trace the progress of this work during the following years, I do not propose to do so, as time will not permit, and you can obtain the original communication from your medical libraries, should you wish to read them.

As there are some here to-night who are not doing radiological work, and are not familiar with the *modus operandi* of this particular branch in radiology, may I explain very briefly the method of examination, what one expects to find in the event of obstruction at certain points in the ventricular system, and what deductions we can make.

By substituting air for cerebro-spinal fluid, the ventricles can be made visible, just as gas in the stomach or intestines will demonstrate the contour of these organs by rendering them more translucent than the surrounding tissues. Fluid is withdrawn from a lateral ventricle and an equal quantity of air injected. The more complete the fluid replacement the better will be the radiological demonstration of the ventricles and the easier the diagnosis. In practice, the smaller the interchange of fluid and air which will enable a diagnosis to be made, the less danger there is to the patient. Total air replacement in a case in which there is already increased intracranial tension is accompanied by severe and often dangerous alteration in the tension, and for this reason this method is contra-indicated.

From the changes produced in the size, shape, or position of the ventricles, we endeavour to deduce the situation of the tumour. Dandy has stated that "all tumours which give signs of intracranial pressure will produce some change in the shape, size, and position of one or more of the ventricles. By that I do not mean that all brain tumours distort or change the size, shape, and position of the ventricles, but that all brain tumours which give symptoms of pressure produce one or more of these changes which would make a diagnosis possible."

Brain tumours give rise to two types of symptoms :—(1) Localizing, (2) those due to general pressure. If the former are present, localization of the tumour is accomplished and there is no necessity for ventriculography. If there are no localizing symptoms, the only other symptoms are those of pressure, and in these the X-ray method should enable a localization to be made.

Dandy has stated, and stated truly, that "there are many pitfalls in the interpretation of X-ray findings; it is not a simple foolproof interpretation : it requires much experience." Before describing the technique of examination, may I refer very shortly to the physiology of the circulation of the cerebro-spinal fluid. All of this fluid is formed in the ventricles, but is absorbed outside the brain. There are four ventricles—two lateral ventricles and the third and the fourth ventricles.

Fluid formed in the lateral ventricles will flow through the foramina of Monro into the third ventricle. Should one of these foramina be blocked, the ventricle on that side will dilate. If fluid is withdrawn from this ventricle and replaced by air, the dilated air-filled cavity will be demonstrable by a radiograph, and the failure of air to pass via the third ventricle into the ventricle of the opposite side when this side is placed uppermost, is further proof of the site of the block. If the other side is now injected with air, one can see whether this ventricle is also dilated. If so, it proves that the tumour involves the third ventricle to such a degree that no fluid can pass through it or only in very small quantities. From the third ventricle there is only one exit, the aqueduct of Sylvius, through which all fluid formed in the lateral and third ventricles must pass. Should the aqueduct of Sylvius become blocked, there will be a general dilatation of the third and the two lateral ventricles.

Assuming the aqueduct of Sylvius is patent, the fluid passes into the fourth ventricle and from thence it flows into the cisterna magna through three openings, two foramina of Luschka and one of Magendi. From the cisterna magna the fluid passes downwards into the spinal canal and upwards into the sub-arachnoid spaces which cover the whole brain.

A sub-tentorial tumour pressing upon the fourth ventricle will produce a general dilatation of the whole ventricular system. One of the objects of ventriculography is, therefore, to determine whether dilatation of the ventricles exists, and if so, where the obstruction occurs. The site of obstruction will be the location of the tumour. An extra ventricular tumour may be detected by the pressure defect it produces upon the ventricles and by displacement of the ventricles.

A tumour of the frontal lobe will deform the anterior horn on the affected side. A tumour of the occipital lobe will compress or displace the posterior horn. A tumour of the parietal lobe will produce a flattening of the body of the lateral ventricle and probably some displacement of both ventricles towards the opposite side. A tumour in the temporal lobe will displace the whole ventricular system towards the opposite side, sometimes deforming them.

Technique.

After injection of the air into the ventricles the patient is sent straight from the operating-theatre to the X-ray department. The radiologist should be told whether both ventricles have been filled or, if the replacement has been unilateral, which side was injected. This is important, as the information will guide one as to the subsequent manipulation of the head which will be necessary in order to make the air pass from one side to the other. Assuming that the right ventricle has been injected with air, the first film may be taken with the head in the lateral position, the right side uppermost. Two films are taken, one with the face downwards towards the table at an angle of thirty degrees to the horizontal plane. In this position the posterior horn of the right ventricle is the highest part of the ventricular system, and will therefore be well filled with air, provided no obstruction exists.

The second lateral film is taken with the face turned away from the table at an angle of thirty degrees from the horizontal plane. In this position the descending horn on the right side is the highest part of the ventricular system, and should be well demonstrated by its air-content. The head should then be turned over on to the right side for a few moments in order to allow the air to pass via the foramina of Munro and the third ventricle into the lateral ventricle of the opposite side.

The third film is then taken with the occiput down, the head perfectly straight, and the line from the outer canthus of the eye to the external auditory meatus at right angles to the table. The tube may be centred vertically over the middle of the frontal bone, or, as advised by Lysholm, may be tilted fifteen degrees towards the cranium. This helps to avoid superimposition of the frontal sinuses over the anterior horns of the ventricles. In this view it is hoped to demonstrate the two anterior horns filled with air; and here it is necessary to remind ourselves that the lateral ventricles as they extend forwards diverge outwards and become expanded to form the anterior horns. If the air is equally distributed between the two ventricles, the anterior horns will present symmetrical shadows. (Plate 2.) Owing to the divergence of the lateral ventricles, composite shadows are produced. The outer and fainter portions are due to air in the anterior horns, while the inner and more translucent areas represent the bodies of the ventricles. The third ventricle will often be shown in this antero-posterior view as a linear shadow just below the anterior horns and in the middle line.

The third and sometimes the fourth ventricles may be demonstrated from a lateral position at this stage of the examination, and before the head is turned to one side or the other. An inverted position of the head is obtained by raising the patient's shoulders and body on pillows. The head is then extended to the maximum degree possible, till the vault of the skull rests upon the table. The film is supported in a vertical position beside the head, and the tube centred so that the central ray passes through a point about an inch above the external auditory meatus and at right angles to the film.

If it is desired to obtain films of the left ventricle, the head is now turned over on to the right side, and a few minutes are allowed to enable the air to rise and fill the left ventricle, which is now uppermost. Two films are now taken in precisely the same manner as for the right side. The patient is then turned completely over on to his face and the head placed in the forehead-nose position. The head is placed so that the line joining the external auditory meatus to the outer canthus of the eye is at right angles to the table. The tube is centred vertically over a point about two inches above the occipital protuberance. The film taken in this position will demonstrate the posterior horns and portion of the bodies of the lateral ventricles. (Plate 3.)

The positions I have indicated will in most cases be sufficient to give the information desired, but each case must be treated on its merits, and other positions may be necessary to elucidate some particular point.

and sometimes more, but, as I have already explained, particular attention must be paid to the special requirements of each case.

The series of radiographs usually includes at least one pair of stereoscopic films

A Potter Bucky diaphragm or Lysholm grid is used as routine, the Lysholm grid being particularly useful for the lateral film with the head in the inverted position.

While in many instances the X-ray findings by this method of examination are precise and give accurate information as to the site of a tumour, in a certain proportion of cases the X-ray evidence is inconclusive and unsatisfactory. Uneven distribution of air and residual pools of cerebro-spinal fluid may produce apparent defects and fallacious conclusions.

I want to refer now briefly to a newer method of examination which has been described by Schonfield and Freeman of Washington in 1933, and by Twining and Rowbotham in the "Lancet" of July, 1935, and which has been tried in a number of cases by Mr. McConnell at the Richmond Hospital. This consists in the introduction of thorotrast into the ventricles. The great advantage of this material is that it is radiopaque and is also diffusible with the cerebro-spinal fluid. Further, it avoids the alteration of intracranial tension which accompanies air replacement. As it mixes with the cerebro-spinal fluid, it possesses the enormous advantage of uniformly demonstrating the whole ventricular system at the one moment. (Plate 4.) The contrast between thorotrast and the surrounding brain substance is usually more striking than between air and brain, and it is therefore particularly suitable for stereoscopic visualization of the ventricles.

The radiographic technique is also simplified. The fact that the whole ventricular system is visualized in whatever position the patient is placed, avoids the multiplicity of films which are sometimes necessary by the piecemeal method of air ventriculography.

The ease with which the third and fourth ventricles can be demonstrated is a very great advantage. A lateral film with the patient in a sitting posture will show these ventricles clearly, thus eliminating the difficult inverted position which is necessary when air is used. We have only used thorotrast in a few cases in the Richmond, but there is no doubt that radiographically the results surpass those obtained by air injection in density, definition, anatomical detail, and more uniform visualization. From the patient's point of view, Twining and Rowbotham state "that the intracranial tension is unaltered and that the not inconsiderable risk of air replacement is obviated."

Some authors have doubted the suitability of thorotrast on account of slow elimination, radio-active and irritative properties. From our small experience we have learned that when there is no obstruction of the fourth ventricle and the thorotrast finds its way through the foramina of Magendi into the sub-arachnoid space, the patient then experiences some degree of shock associated with headache and sweating.

In the cases investigated by Twining and Rowbotham, 25 c.c. of fluid was withdrawn from the ventricles, and 10 c.c. of air introduced followed by 10 c.c. of thorotrast. The thorotrast was poured into the funnel for the reception of the cerebro-spinal fluid and mixed with it by agitation. It was then run into the ventricle by raising the funnel. The resulting shadows were very satisfactory, and two hours later a film showed that almost all the thorotrast had left the ventricular system. The method adopted by Mr. McConnell was similar to that of Twining and Rowbotham, except that air was not always injected.

The question is often asked: What becomes of thorotrast eventually?

A case had been injected with thorotrast five months before. Ventriculography with air was done recently, and it showed that small quantities of thorotrast were still adherent to the walls of the ventricles, and a film of the lumbar region showed the cauda equina clearly demonstrated by the opaque material.

In conclusion, I should like to say that ventriculography is not free from danger to life, and should only be carried out after all other methods of examination have failed to enable one to make a diagnosis.

With regard to thorotrast, I do not think that very much is yet known as to its after-effects or whether its introduction does any permanent harm. From a purely radiographic standpoint it possesses one outstanding advantage over air, i.e., the ease with which the third and fourth ventricles can be demonstrated, even after the introduction of a very small quantity of thorotrast. (Plate 5.) The visualization of these ventricles is of paramount importance in cases of hydrocephalus, because one can determine with some degree of accuracy the position of the obstruction. The value of this lies in the fact that the surgical approach varies greatly according to the site of the lesion. An approach from a wrong direction leads to great difficulties in operation and possibly a fatal result.

Dr. Hardman's Paper

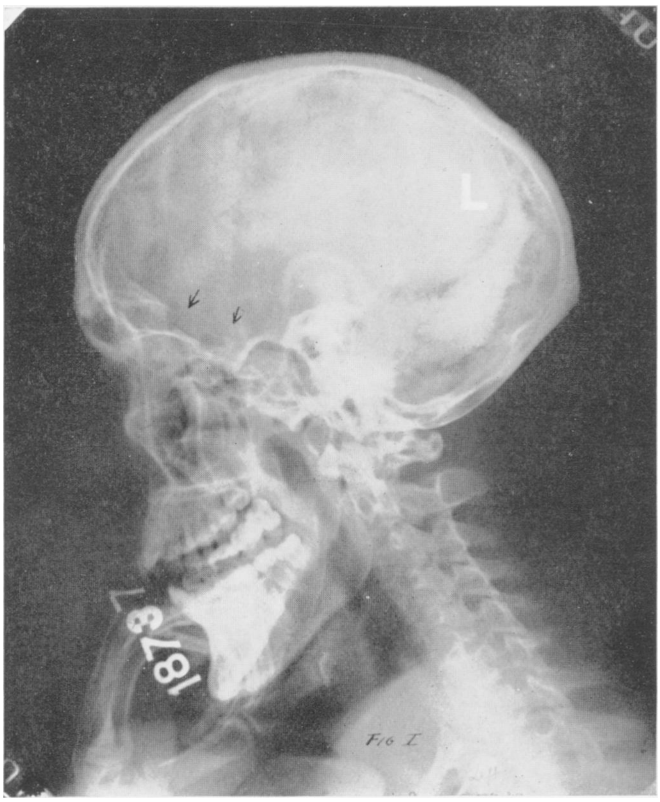

PLATE 1.

Deformity of sella turcica and extensive destruction of the anterior floor of cranial fossa due to increased tension associated with tumour of fourth ventricle.

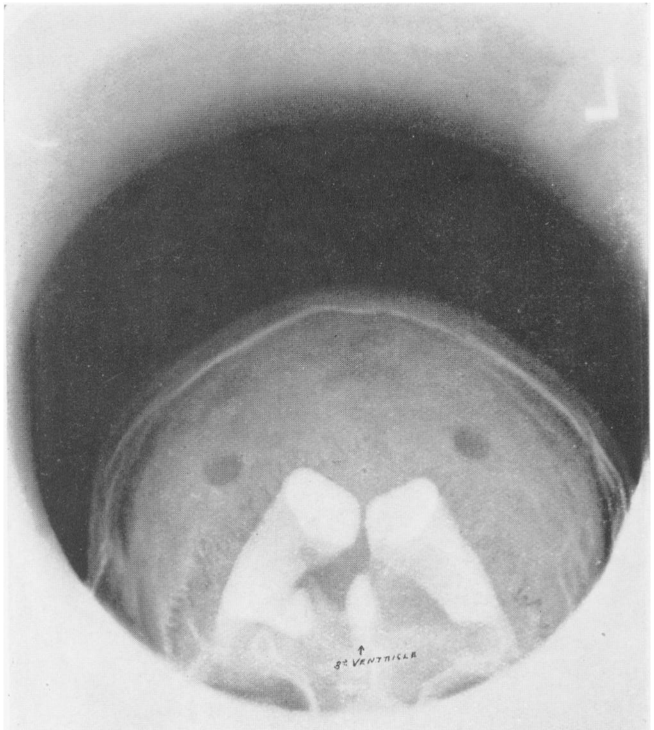

PLATE 4.

Whole ventricular system demonstrated by thorotrast.

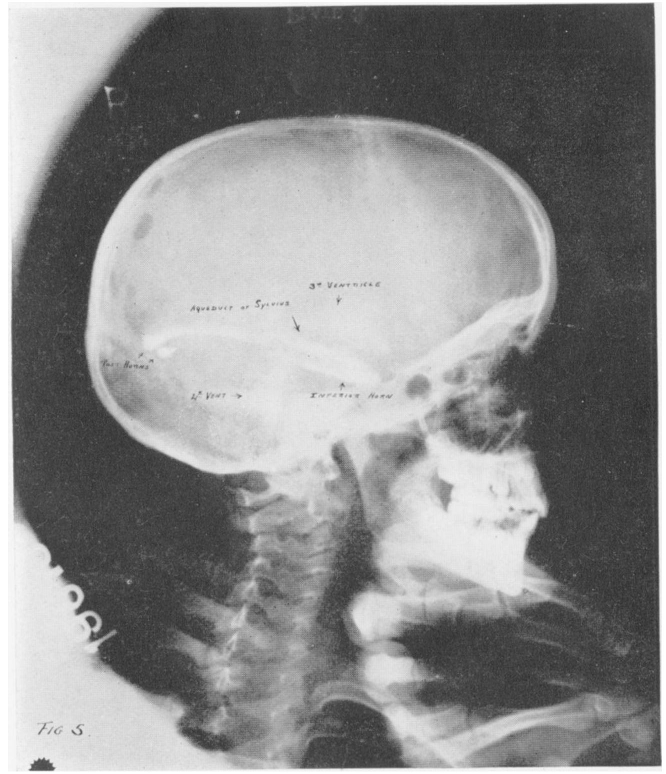

PLATE 5.

Third and fourth ventricles clearly demonstrated by a very small quantity of thorotrast. Upright position.

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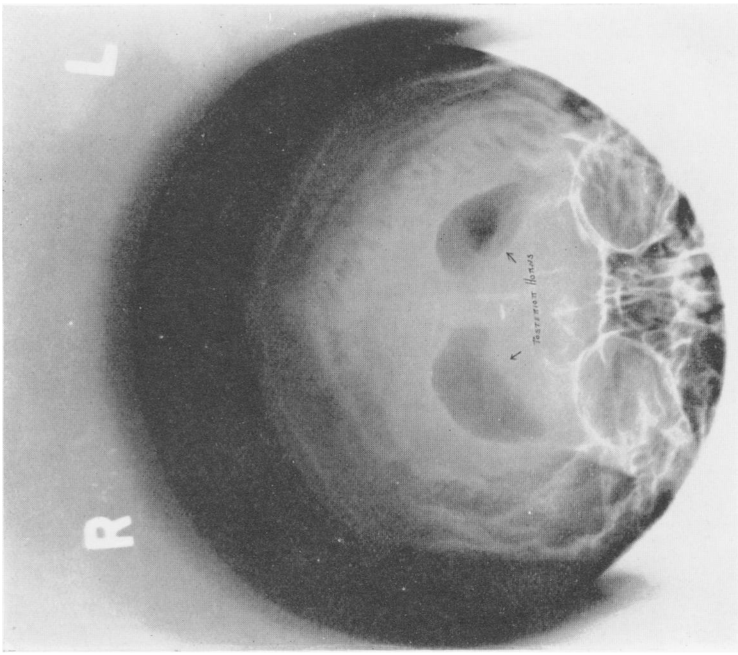

PLATE 3.
Posterior horns.

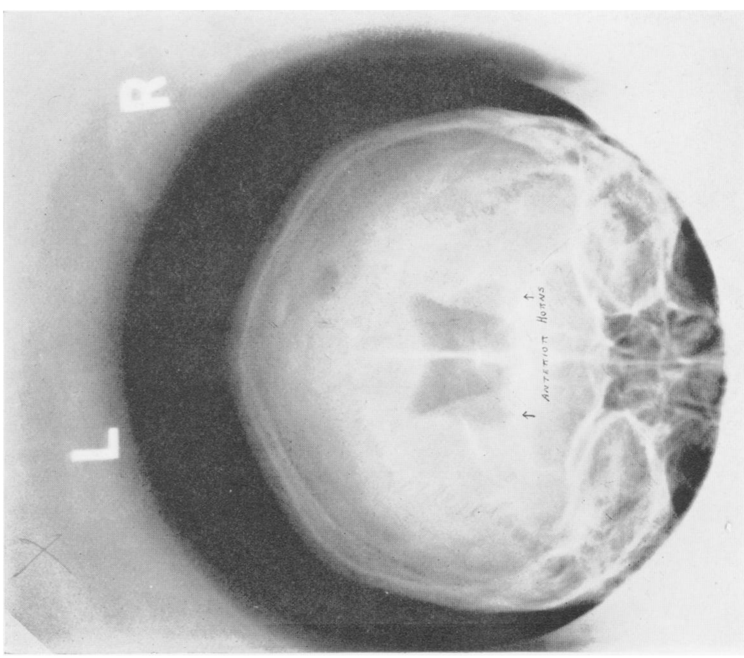

PLATE 2.
Anterior horns.